Microbial Degradation Studies in Pulp and Paper Industries

A Synopsis

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Introduction:

Pulp and paper mills are categorized as a core sector industry and are the fifth largest contributor to industrial water pollution. The production in 2005-2006 was 5.9 million tons. The present paper consumption is low at 6 kg /capita. However with rise in literacy, education and income level, it is estimated that the demand would be over 14 million tons in 2020 (Jaakko povry management consulting, 2002). The India pulp and paper industry is highly water intensive consuming 100-250 m^3 freshwater/ton paper. The corresponding waste water generation is also high (75-225 m^3 waste water/ton paper. As per the Ministry of Environment and Forest (MoEF), Government of India, the pulp and paper sector is in the "Red Category" list of 17 industries having a high polluting potential owing to its serious pollution threat. It is mandatory for pulp and paper mills to take appropriate standards set by Central Pollution Control Board (CPCB) (Tewari et al., 2009). Pulping and bleaching are two main processes involved in the manufacturing of paper. The effluent generated at the pulping stage is dark brown in colour (black liquor) due to dissolved lignin, and its degradation products, hemicelluloses, resins, acids and phenols. The effluent generated at bleaching stage has absorbable organic halogens (AOX), peroxides and other such derivatives of lignin and hemicelluloses .It is estimated that 1 ton of paper generates 150 m^3 of effluent which is extremely toxic in nature (Pokhrel and Viraraghavan, 2004).

Various studies have reported detrimental effects of pulp and paper mill effluent on animals living in water bodies receiving these effluents. The effects are in form of respiratory stress, liver damage and geno-toxicity. A study in 1996 reported health impacts such as diarrhea, vomiting, headaches, nausea and eye irritation on children and workers due to the pulp and paper mill wastewater discharged to environment. The effluent has high chemical diversity of organic chemicals present in it. Another study reports the toxic and mutagenic effects of pulp and paper mill effluent contaminating lake Baikal. Exposure to the effluent adversely affects diversity and abundance of phytoplankton, zooplankton and zoobenthos, disrupting benthic algal and invertebrate communities. Therefore it is obligatory to treat the effluent before disposal (Singhal and Thakur, 2009).

In general, the effluent is concentrated and then burned to generate electricity. While burning many toxic volatile organic compounds are formed. The alternative is adopting biological treatment that involves the use of fungi and bacteria. Commonly used physical and chemical treatment methods are electro coagulation, ultrasound, reverse osmosis, photo catalytic systems using titanium dioxide (TiO_2), zinc oxide (ZnO) under UV/solar irradiation, hydrogen peroxide, Fenton`s reagent (H_2O_2 /Fe^{2+}), UV,

one (ozone/ H_2O_2). Biological treatment studies confined themselves to the evaluation of microorganism, basic mechanism behind treatment and changes in the effluent after treatment. The microorganism treats the effluents mainly by two processes: action of enzymes and biosorption. The various enzymes involved in the treatment of pulp and paper mill effluent are lignin peroxidases, manganese peroxidase and laccase. Microorganisms showing good production of these enzymes have the potency to treat the effluent (Singhal and Thakur, 2009).

The most widely used biological treatment system is activated sludge process. However it also is ineffective in total removal of color and toxicity of the effluents. In past , a number of physical-chemical treatment systems based on precipitation, coagulation , adsorption , and membrane filtration have been applied to remove color and toxicity of these effluents , but none of these have been found to be industrially applicable , due to one or another drawback (Malaviya and Rathore, 2007). Although the physical and chemical methods are on the track of treatment, they are not on par with biological treatment because of cost ineffectiveness and residual effects. The biological treatment is known to be effective in reducing the organic load and toxic effects of kraft mill effluents (Thakur, 2004). Thus there is a need to search or develop a suitable low cost biologically or environmental friendly methods for bioremediation of pulp and paper mill effluent which have the capacity of efficient biodegradation of organic and inorganic pollutants of mill effluents.

Review of Literature:

The rapid increase in population and the increased demand for industrial establishments to meet human requirements have created problems such as overexploitation of available resources, leading to pollution of the land, air and water environments (Pokhrel and Viraraghavn, 2004). Wastewaters discharged by the industries are one of the major causes of environmental pollution, particularly in the developing countries. Pulp and paper manufacturing is one of the oldest and largest industry in India with an installed capacity of about three million metric tones per annum finished product (Malaviya and Rathore, 2007). The Indian pulp and paper industry is highly water intensive, consuming 100-250m^3 freshwater/ton paper. The corresponding wastewater generation is also high (75-225 m^3 wastewater/ton paper. As per the Ministry of Environment and Forest (MoEF), Government of India, the pulp and paper sector is in the “Red Category” list of 17 industries having high polluting potential. Owing to its serious pollution threat, it is mandatory for pulp and paper mills to take appropriate measures to comply with the discharge standards set by the Central Pollution Control Board (CPCB), which is the national agency

responsible for environmental compliance. The environment impact of paper and pulp mills is of particular concerns since these units generates 150-200m^3 effluent/ton paper with a high pollution loading of 90-240 kg suspended solids/ton paper, 85-370 kg biochemical (BOD)/ton paper and 500-1100 kg chemical oxygen demand (COD)/ton paper. Apart from the pollution, there is a growing water scarcity and deterioration in water quality in many parts of India. Thus, in the context of reduced freshwater availability, declining water quality and environmental pollution from inadequately treated effluent, there is an urgent need for efficient water management in pulp and paper mills (Tewari et al., 2009). About 500 different chlorinated organic compounds have been identified in paper mill effluent. The high chemical diversity of these pollutants causes a variety of clastogenic, carcinogenic, endocrinic and mutagenic effects on fishes and other aquatic communities in recipient water bodies (Malaviya and Rathore, 2007). Paper and pulp mill is a source of major pollution generating industry leaving huge amount of intensely colored effluent to the receiving end. The recent researches on biodegradation of pulp and paper mill effluents are to identify predominant bacteria and fungi in paper and pulp mill effluent in addition to evaluate the degradation efficiency of individual isolates and combination of isolates. The pulp and paper mill is one of the most polluting industries that discharge a variety of gaseous, liquid, and solid wastes in the environment. Effluent generated from paper and pulp mills is heavily loaded with organic compounds depending on the nature of the raw material, process and chemicals used; finished product and extent of water reused. Manufacturing of paper involves two main processes: pulping entirely different in nature and need specialized treatment. The effluent generated at the pulping stage (black liquor) contains various compounds like dissolved lignin and its degradation products, hemicelluloses, resins acids, fatty acids, tannins and phenols (Ali and Sreekrishnan, 2001; Malaviya and Rathore, 2007). These organic compounds are also responsible for giving the effluent its characteristic dark brown colour toxicity. Thus it is obligatory to treat the effluent before disposal.

Biological treatment methods involved the use of fungi, bacteria algae and enzymes as a single step treatment or in combination with other physical and chemical methods .The biological treatment studies have confined themselves to the evaluation of microorganism, basic mechanism behind treatment and changes in the effluent after treatment .Not even a single study has optimized the process of effluent treatment. The microorganism treats the effluents mainly by two process; action of enzymes and biosorption (Malaviya and Rathore, 2007). Microbial enzymes are enabling new technologies for processing pulps and fibers. Xylanases reduce the amount of chemicals required for bleaching; cellulases smooth fibers, enhance drainage, and promote ink removal; lipases reduce pitch; lignin-

degrading enzymes remove lignin from pulps. Several of these processes are commercial, and others are beginning to emerge. In the future, enzyme-based processes could lead to cleaner and more efficient pulp and paper processing. Treatment efficiency of individual isolates and combination of isolates are evaluated by shake flask method. Combination of *Pseudomonas alkaligenes*, *Bacillus subtilis* along with *Trichoderma reesei* shows higher BOD, COD reduction of 99% and 85% respectively. As individual isolates *Pseudomonas alkaligenes* show 92% BOD reduction and 77% COD reduction over other bacterial isolates and *Trichoderma reesei* removed 99% BOD and 80% COD respectively (Saravanan and Sreekrishnan, 2005).The performance and enzymatic strategy exhibited by basidiomycete Euc-1, a laccase producing strain, was investigated during the biodegradation of olive oil mill wastewater (OMW)this strain yield better decolorization of solidified OMW than *Phanerochate chrysosporium* and removed 90% of phenols (Dias *et al,* 2004). An investigation was conducted to explore the ligning-degrading capacity of attached growth white-rot fungi (*Phanerochate chrysosporium, Pleurotus ostreatus, Lentinus edodes, Trametes versicolor and S22*). Over 71% of lignin and 48% of chemical oxygen demand (COD) were removed from the wastewater. Two basidiomycetous fungi (*Merulius aureus* syn. *Phlebia* sp.) and a deutromycetous fungus (*Fusarium sambucium* Fuckel MTCC 3788) were isolated from soils affected with effluents of a pulp and paper mill over several years. These were immobilized on nylon mesh and the consortium was used for bioremediation of pulp and paper mill effluent in a continuously aerated bench top reactor. The treatment resulted in the reduction of color, lignin and COD of the effluent in order of 78.6%, 79.0%and 89.4%. The various enzymes involved in the treatment of pulp and paper mill effluent are lignin peroxidase, manganese peroxidase and laccase (Malaviya and Rathore, 2007). Microorganisms showing good production of these enzymes have the potency to treat the effluent. The biological treatment is known to be effective in reducing the organic load and toxic effects of (Thakur, 2004).

Justification/ Importance of Work:

As per the ministry of environment and forest (MoEF), Government of India, the pulp and paper sector is in the "Red Category" list of 17 industries having a high polluting potential. Owing to its serious pollution threat, in past, number of physical –chemical treatment systems based on precipitation, coagulation, adsorption and membrane filtration have been applied to remove color and toxicity of these effluents, but none of these have been found to be industrially applicable, due to one or another

drawback. Microorganism rapidly degrade many chemicals and thereby eliminate them from the environment, other are degraded slowly, accumulate in the environment and occasionally exhibit toxicity. Thus it is the need to search or develop a suitable low cost biologically or environmental friendly method for bioremediation of pulp and paper mill effluent have capacity of efficient biodegradation of organic and inorganic pollutants of mill effluents, and having high capacity and rate of adsorption, high selectivity for different concentrations and tolerant of a wide range of wastewater parameter. In our view microorganism may be active at wide range of environment (pH, temp, pollutant concentration etc.) and fulfill the need of today for effective treatment of industrial effluents.

Problem Definition:

- Collection of soil sample from the pulp and paper industry
- Study the physical parameters of soil and water
- Isolation of microorganisms from soil and water sample.
- Identification of microorganisms
- Screening of microorganism for cellulase enzyme
- Quantitative estimation of cellulase enzyme
- Screening of microorganism for xylanase enzyme
- Quantitative estimation of xylanase enzyme
- Biocontrol studies of pulp and paper industries microorganism
- Molecular characterization of microorganism.

Methodology:

- Collection of soil and water sample from the pulp and paper industry area
- Study the physical parameters of soil and water (pH, temp, colour, acidity and alkanity)
- Isolation of microorganisms from soil and water sample:-By serial dilution method (Saraswathi and Saseetharan, 2010)
- identification of microorganisms from soil and water sample:-By colony morphology, gram staining, microscopic observation and confirmation test (Saraswathi and Saseetharan, 2010)

- Screening of microorganism for cellulase enzyme:-By extracellular method (Rafique et al., 2010)
- Quantitative estimation of cellulose enzyme:- By cellobiose assay & filter paper assay (Ghose , 1987)
- Screening of microorganism for xylanase enzyme:- By extracellular method
- Quantitative estimation of xylanase enzyme:-By enzymatic assay(Mishra and Dadhich, 2010)
- Biocontrol studies of pulp and paper industries microorganism:- By dual culture (Montealegre et al., 2003)
- Molecular characterization of microorganism

Place of Work and Facilities Available:

Different Laboratories of Jayoti Vidyapeeth Women's University, Jaipur i.e. Microbiology lab, Instrumentation lab, Biochemistry lab, Bioscience lab, Pharmacology Lab.

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